MULTIMEDIA UNIVERSITY

STUDENT ID NO

MULTIMEDIA UNIVERSITY

FINAL EXAMINATION

TRIMESTER 2, 2015/16

ENT3036 – SEMICONDUCTOR DEVICES

(All sections / Groups)

01 MARCH 2016
2:30 P.M- 4:30 P.M.
(2 Hours)

INSTRUCTION TO STUDENTS

1. This Question paper consists of 4 pages with 4 Questions only.

2. Answer all the questions and all the questions carry equal marks of 25. The distribution of the marks for each question is given.

3. Please print all your answers in the Answer Booklet provided.

Question 1

(a) The following parameters have been identified for an ideal abrupt semiconductor p-n junction with a junction area of 2×10^{-5} cm^2 at an ambient temperature of T = 300 K.

p-side: Acceptor/Hole concentration $(N_A) = 6\times10^{17}$ cm^{-3}
Electron carrier mobility $(\mu_n) = 900$ cm^2/Vs
Hole carrier mobility $(\mu_p) = 500$ cm^2/Vs

n-side: Donor/Electron concentration $(N_D) = 6\times10^{17}$ cm^{-3}
Electron carrier mobility $(\mu_n) = 500$ cm^2/Vs
Hole carrier mobility $(\mu_p) = 300$ cm^2/Vs

Let
Intrinsic carrier concentration $n_i = 1.6\times10^{10}$ cm^{-3}
Energy gap $E_g = 1.6$ eV
Permittivity $\varepsilon_s = 10$

(i) Calculate the built-in potential across the p-n junction at equilibrium.
(3 marks)

(ii) Determine the depletion widths at both sides of the p-n junction at equilibrium.
(4 marks)

(iii) Estimate the maximum electric field across the p-n junction at equilibrium.
(2 marks)

(iv) Draw the distribution profile for the electric field across the p-n juction at equilibrium.
(2 marks)

(b) Emitter current (I_E) for an npn bipolar transistor is measured and is found to be 1.2 mA. Calculate the base-emitter voltage (V_{BE}) if parameter of the transistor is listed as follow.

Common-emitter current gain, β	150
Cross-sectional area of the base emitter junction, A_{BE}	1.4×10^{-3} cm^2
Neutral base width, x_B	0.70 μm
Thermal-equilibrium electron concentration in the base, n_{B0}	2.3×10^{3} cm^{-3}
Minority carrier electron diffusion coefficients in base, D_n	19 cm^{2}s^{-1}

(8 marks)

Continued...

(c) With suitable graphs, describe the following non-ideal effects of a bipolar junction transistor:
(i) Nonuniform base doping; (3 marks)
(ii) Punch-through breakdown. (3 marks)

Question 2

(a) A GaAs p-channel pn JFET has gate doping concentration at $N_d = 1.8\times10^{18}$ cm^{-3} and channel doping concentration at $N_d = 1.3\times10^{16}$ cm^{-3}. Determine the channel thickness in order to obtain pinch off voltage (V_p) at 3.05V. (8 marks)

(b) Sketch the high frequency small-signal equivalent circuit of JFET and label the terminals and components in the circuit clearly. (8 marks)

(c) Explain briefly the two nonideal effects that could occur in JFET. (3+3 marks)

(b) Draw the capacitance-voltage (C-V) characteristic exhibited by an ideal MOS capacitor with an n-type semiconductor. Label the bias conditions for accumulation, flatband, depletion and inversion in the graph clearly. (3 marks)

Question 3

(a) An ideal MOS capacitor with a p-type semiconductor has impurity concentration of 8.5×10^{16} cm^{-3} and the oxide capacitance (t_{ox}) of 7.8×10^{-8} F/cm^2. It is given that intrinsic concentration (n_i) = 1.5×10^{10} cm^{-3}, permittivity of semiconductor (ε_s) = 11.7, permittivity of insulator (ε_i) = 3.9 and temperature (T) = 300 K.

Determine
(i) the thickness of oxide layer, t_{ox} (4 marks)

(ii) the minimum capacitance achieved, C_{min} (6 marks)

(iii) and the threshold voltage, V_T. (3 marks)

(b) Indicate three regions of operation for Metal-Oxide-Semiconductor Field Effect Transistor (MOSFET) in output current versus output voltage characteristics. Briefly explain these regions of operation for MOSFET. (4+8 =12 marks)

Continued...

Question 4

(a) (i) By using a simplified band diagram of gallium arsenide (GaAs), explain briefly the occurrence of negative differential resistance in Gunn diode. (3 marks)

(ii) List the two processes which induce negative conductance occurrence in IMPact ionization Avalanche Transit-Time (IMPATT) diode. (2 marks)

(b) Draw the voltage – time (v-t) graph of the three domain modes for a Gunn oscillator and clearly indicate their differences. (6 marks)

(c) Gunn diode or Transfer Electron Device (TED) is a negative differential resistance device. Describe THREE (3) fundamental differences between TED and microwave transistor. (8 marks)

(d) How to improve the efficiency and the power of Avalanche Transit-Time (IMPATT). Give two applications of IMPATT diodes. (6 marks)

PHYSICAL CONSTANT:

Thermal voltage:	$V_t = 0.0259$ V
Intrinsic concentration of Silicon at 300K:	$n_i = 1.5\times10^{10}\,\text{cm}^{-3}$
Intrinsic concentration of Silicon at 373K:	$n_i = 2.5\times10^{12}\,\text{cm}^{-3}$
Intrinsic concentration of Gallium Arsenide at 300K:	$n_i = 1.8\times10^{6}\,\text{cm}^{-3}$
Boltzmann's constant:	$k = 1.3806\times10^{-23}$ J/K
Electronic charge:	$e = 1.6\times10^{-19}$ C
Permittivity of free space:	$\varepsilon_0 = 8.85\times10^{-14}$ F/cm
Dielectric constant of Silicon at 300K:	$\varepsilon_r = 11.7$
Dielectric constant of Silicon oxide at 300K:	$\varepsilon_i = 3.9$
Dielectric constant of Gallium Arsenide at 300K:	$\varepsilon_{GaAs} = 13.1$

End of paper.